UNITED
NATIONS

A

General Assembly

Distr.
GENERAL

A/AC.105/470/Add.2
15 April 1991
ENGLISH
ORIGINAL: ENGLISH/RUSSIAN

COMMITTEE ON THE PEACEFUL
USES OF OUTER SPACE

INTERNATIONAL COOPERATION IN THE PEACEFUL USES OF OUTER SPACE - ACTIVITIES OF MEMBER STATES

Note by the Secretariat

Addendum

The present document contains information provided in replies received from Member States up to 12 April 1991.

CONTENTS

	Page
HUNGARY	2
UNION OF SOVIET SOCIALIST REPUBLICS	9

HUNGARY

[Original: English]

INTRODUCTION

Space research in Hungary started in 1967 when the Intercosmos Cooperation Agreement was signed between the Union of Soviet Socialist Republics and several Eastern European countries. Our work in this field consists of wide-ranging, solidly based international cooperation. Our most important partner is the Soviet Union and our joint research is carried on primarily within the framework of the Council on International Cooperation in Research and Uses of Outer Space (INTERCOSMOS) programme in the following areas:

- space physics;
- space biology and medicine;
- satellite-assisted exploration of natural resources (remote sensing);
- satellite meteorology;
- space communication.

Hungary has not set a goal of becoming a major space Power. But space activities, proportional to our capabilities and means, may reward Hungarian science with success out of proportion.

The results of this cooperative effort are utilized in several fields for a variety of purposes. Our scientists are afforded the chance to take part in unique experiments: they regularly obtain new data and up-to-date information about space, the Earth and other celestial bodies, and about the effects of weightlessness. Some of these data, especially those concerning meteorology and the exploration of natural resources, are already being put to practical use. Hungarian engineers take part in the development of measurement techniques and in the construction of scientific instruments applicable not only in space research, but also in industry, medicine and education.

The following report has been compiled by the secretariat of the Intercosmos Council of the Hungarian Academy of Sciences, 11 1369 Budapest, P.O.B. 315, Hungary.

I. SPACE RESEARCH

Particular emphasis is given to the following space activities.

A. Space physics

In the field of magnetosphere and ionosphere physics the research has been continued, including theoretical studies and analysis of observations by instruments on board the satellite Active.

During 1990, a significant part of the research activities was concentrated around the study of the environment of Mars, comets and interplanetary space.

The measurements performed by plasma instruments on board the Phobos spacecraft around Mars were further analysed, yielding several important new results. Irregular plasma and magnetic field disturbances were observed aboard the Phobos 2 spacecraft in a few cases when it crossed the Phobos moon's orbit, raising questions about the possible existence of a dust torus around Mars. The origin of dust grains can be attributed to micrometeoroid bombardments on the surface of the Martian satellites. The motion of ejected particles larger than 1μ is mainly influenced by gravity, while the orbital evolution of submicron-sized grains can significantly be infuenced by solar radiation and by Lorentz forces. Submicron-sized grains form a time-dependent and non-uniform dust halo around Mars. If there is a dust belt along the orbit of Phobos, it must consist of particles much larger than 1μ.

A comparative study has been performed on the magnetic environment of Mars and Venus, in particular, concerning the nature of the surface separating plasmas of solar and planetary origin and the physical processes going on around it.

Image processing of the pictures of Halley's comet taken by the two Vega spacecraft has been continued. Based on data obtained from these images together with those of Giotto, the equations of motion of the cometary nucleus have been solved. The nucleus can be described by an ellipsoid of inertia with axes 16 x 8 x 7 km long, rotating around the shortest axis with a period of 2.24 days while the long axis nods up and down with a period of 7.66 days. This solution agrees with observations of curvature of jets and brightness variations.

Hungary is participating in the preparation of an atlas of Vega images for the archives of the International Halley Watch.

The investigation of the plasma environment of Halley's comet has been continued by combining ion and electron data with magnetic field and plasma wave observations. The increase in the level of lower hybrid and whistler mode waves around the cometopause was explained by the presence of implanted cometary ions.

Based on ISEE-3 measurements, angular and spectral behaviour of particle populations have been determined through shocks and have been compared with the predictions of the so-called gradient drift acceleration model. Time-reversed numerical simulation of particle trajectories showed that sudden particle enhancements close to the shock are not readily explainable by scatter-free acceleration alone.

B. Space biology and medicine

In the late 1960s, Hungarian physicians were the first to join the biomedical research activities of the Intercosmos space research cooperation programme. Scientific investigations were greatly stimulated by the first Soviet-Hungarian space flight. At present there are 13 teams of Hungarian research workers taking part in this activity and their studies range over three fields of space biomedical research, i.e., space physiology, space radiation protection and biology, and space pyschology.

Scientific investigations in the Institute of Aviation Medicine cover all three of these fields. During recent years, studies of applied physiology have been focused on developing objective testing methods to assess the actual working capacity in man. The peak and the reserves of human performance are assessed in a measurement unit by continuous monitoring of the cardiovascular and respiratory systems during treadmill exercise. Another objective testing method is the 26-hour recording of the cardiac activity on a magnetic tape and the computer-assisted analysis of the data obtained. This method permits continuous monitoring of cardiac parameters even in real flight.

The other essential factor of the actual working capacity is mental performance. Psycho-emotional state and mental performance are investigated. The Balaton device, developed by the time of the Soviet-Hungarian space flight, is very helpful in the comprehensive assessment of mental state. A computer program for data processing of these multi-parametral psychological measurements has been also developed. Results of the experiments carried out in cooperation with the Soviet research workers may be used well in the selection of cosmonauts, in preflight, inflight and postflight assessment of working capacity.

A method to simulate the physiological effects of weightlessness has been developed at the Institute of Aviation Medicine. The main element in it is a cage limiting the movement of the animals. Using this method, the Biochemical Institute of Albert Szent-Györgyi Medical University, Institute of Physiology and Institute of Pathophysiology of the Debrecen Medical University, investigated the effect of hypokinesia on the muscular system.

Studies of the effect of hypokinesia on the gastro-intestinal tract were performed together with research workers of the Institute of Pathophysiology, Semmelweis Medical University. Those experiments have contributed to a better assessment of changes arising in the different organs under the effect of weightlessness.

Besides educational work, the interest of the research workers of the Biochemical Institute, Albert Szent-Györgyi Medical University, is focused on biological differentiation. Changes in the circulatory system and biochemical and biophysical alterations in the skeletal muscles during weightlessness have been first of all studied.

II. APPLIED SPACE RESEARCH

A. Remote sensing

The activity in the field of natural resources management and thematic mapping is based mainly on four complementary, medium-term programmes, supported and coordinated by the State Office for Technical Development and the Intercosmos Council of the Hungarian Academy of Sciences. About 50 executing institutions are involved in the programme, partly in international cooperation. As far as data acquisition and remote sensing oriented hardware/software systems are concerned, new developments in data collection technology are as follows: a dual-frequency microwave radiometer (including air-ground telemetry and mobile in-site analysis workstation) for soil moisture aerial survey and mapping has been elaborated. The system operates L- and S-band microwave and thermal infrared sensors. The software development is executed in cooperation with India.

A 9.4-GHz X-band side-looking real aperture airborne radar (SLAR) for all-weather applications is also under construction.

For remote monitoring and three-dimensional mapping of atmospheric pollution, laser radar technology was developed. This LIDAR technique is useful also for assessing biomass, identifying plant types and estimating timber yields. Further applications incude the measurement of hydrocarbon leakage from pipelines or storage tanks as well as the assessment of toxic gases in industrial environments.

Of use also for ground truth verification of satellite data (especially the European Remote Sensing Satellite ERS-1's Synthetic Aperture Radar), a computer-controlled, dual-polarized X-band scatterometer was developed and tested.

A field spectrometer for use in (satellite and in-situ) comparative investigations of spectral signatures of objects was developed and used in several international campaigns orchestrated by Intercosmos cooperation. Similar spectral assessments and reflectance measurements were executed in soil and vegetation mapping, water quality analysis using commercially available spectrometers and SPOT satellite imagery. Convenient for ground truth measurements, mobile stations have been designed and built for use in geology and mineral exploration, a transportable field radar operating in the 400-500 MHz range was developed.

In imaging spectrometry governmental bodies have contracted the FOMI Remote Sensing Centre (RSC) to organize an international aerial survey using the Canadian Moniteq's Fluorescence Line Imager (FLI) in order to collect and archive data on land quality in the Szigetkoz area. This Szigetkoz campaign was the very first application of a high-technology 288-channel push-broom imager in East Central Europe.

In the preprocessing of high-resolution remotely sensed data, service is provided to meet the requirements of the user community and in conformity with the recommendations of the European Space Agency (ESA) for national centres. For example, at the FOMI RSC a full range of in-house developed software is available for data integration, digital image analysis, pattern recognition and I/O operations in Pericolor, Colormation and MicroVax environments. The local area network was upgraded with the installation of the ARC/Info interactive graphical subsystem of the European Systems Research Institute (ESRI).

For the processing of remotely sensed data from satellites, a high-performance, interactive image processing workstation called Atlas-90, using a pipeline technique and a programmable high-precision digitizer was developed by the industry. A different-level, low-cost professional personal computer based on general-purpose picture processing systems, capable of remote-sensing applications, has been developed and offered by different companies. The integrated land and watershed management information system of the International Telecommunication Union (ITU), a second-generation GIS, was installed for use in environment management.

In the last two years, terrain modelling, automatic slope categorization, orthophoto-processing and advanced photogrammetric data collection techniques have been developed and provided by various institutions. Based on 10 years of experience, postgraduate courses are organized by the Chair of Photogrammetry at the Budapest University of Technology. Moreover, at least five additional educational institutions have graduate and/or postgraduate courses related to remote sensing. Lectures on remote sensing are also given to agricultural managers and the subject will be introduced in the annual international postgraduate course which has been organized by VITUKI under the sponsorship of the United Nations Educational, Scientific and Cultural Organization (UNESCO) since 1966.

A multilingual dictionary on remote sensing has recently been published by the Hungarian Astronautical Society. Based on this multilingual dictionary, a version in the Hungarian language has been edited and published by FOMI RSC for its customers and university students.

B. Materials science in space

Crystallization experiments on eutectics have been continued. The programme of experiments to be performed with the new ABC furnace has been worked out and the starting parameters determined.

C. Satellite geodesy

Activities in this field have been concentrated around photographic, Doppler and laser observations of satellites together with micro-accelerometer (in-situ) measurements to improve the accuracy of ground coordinates for geometric and geodynamic studies.

D. Satellite meteorology

In 1990 a primary data users' station (PDUS) for receiving digital satellite data from Meteosat was installed. The digital receiving station for satellites of the National Oceanic and Atmospheric Administration (NOAA) (United States of America) is being tested. In the weather forecasting services different enhancements of Meteosat images are utilized. In the research work the digital satellite information is the main database for the investigations.

A programme package enabling us to accomplish 31 different enhancements and transformations in the satellite pictures was developed. Research studies were conducted to improve the classifying algorithms in satellite images. Using visible and infrared data from the Japanese satellite MOS-1, an attempt was made to determine some parameters (cloud amounts, cloud forms) of the cloud field.

Information content of thermal radiance data was studied in order to work out an optimum strategy for the evaluation of vertical profiles. The earlier method for determining the global radiation on the ground surface from digital satellite data was advanced by incorporating a radiative convective model using radio-sounding data.

To establish the comparability of vegetation indices derived from measurements by different satellites, a comparison was made between MESSR data from MOS-1 and MSS data from Landsat-5. A further comparative study was performed among Landsat-5, MOS-1 and Cosmos-1939 data taken in the visible and near infrared spectra in order to examine the separability of different surface types by the maximum likelihood and Bayes methods.

The first steps were taken to develop the methodology for consolidating the satellite meteorological data into a geocoded information system.

E. Space communications

In the domain of space communications, Hungarian activities can be classified into two categories:

(a) On the theoretical level, research has been continued on new methods of transmitting and processing various signals:

(i) Increasing the efficiency of signal transmission considering the statistical characteristics of speech signals and the telephone information flow of satellite channels;

(ii) Control methods for data and telephone base bands, and for SCPC signal transmitting systems and equipment;

(iii) Methods and systems for connecting satellite and terrestrial digital transmission channels;

(b) Practical research was carried out in the following areas:

(i) Corrective coding algorithms for digital radio channels;

(ii) Simulations and implementations of digital source coding-decoding equipments for video signals;

(iii) Wave propagation measurements in the 11/12, 18, 22 and 30GHz bands;

(iv) Space-to-Earth propagation measurements in the 11/12 GHz band.

III. INTERNATIONAL COOPERATION

Our space activities were based entirely on international cooperation, in which the INTERCOSMOS programme played a fundamental and decisive role. The work we did and the space communication service we operated within the framework of the International Space Communication System of the International Organization of Space Communications (INTERSPUTNIK) is also very important. Close and fruitful cooperation has developed between Hungary and the Soviet Union and other countries within the INTERCOSMOS programme. We hope this fruitful cooperation will be continued in the future.

In the course of devising instruments for the different space probes, we have developed close links with researchers from Austria, France, Germany and the United States. Our relations with ESA and the National Aeronautics and Space Administration (NASA) of the United States have widened. With a view to the mutual advantage to be obtained, our aim is to further develop fruitful cooperation with other national and international organizations. We have begun formal negotiations with the European Space Agency and also with NASA to foster cooperation in forthcoming space programmes.

To the best of our ability we do participate in the work of the specialized committees of the United Nations. Our representatives are members of the Committee on Space Research (COSPAR) and the Bureau of the International Astronautical Federation (IAF), and we regularly participate in and give lectures at the meetings of those organizations. Several Hungarian scientists are members of the International Astronautical Academy (IAA).

UNION OF SOVIET SOCIALIST REPUBLICS

[Original: Russian]

I. INFORMATION ON SPACE OBJECTS LAUNCHED BY THE USSR IN 1990

In 1990, the USSR launched 96 space objects of various descriptions:

- 66 Cosmos-series satellites (Cosmos-2055 to Cosmos-2120);
- 3 manned spacecraft of the Soyuz TM series (Soyuz TM-9 to Soyuz TM-11);
- the Kristall specialized module for providing equipment to the Mir station;
- the Gamma unmanned astrophysical observatory;
- 4 Progress unmanned cargo vehicles (Progress-42, Progress M-3 to Progress M-5);
- 4 satellites of the Resurs-F series;
- 2 satellites each of the Raduga and Meteor-2 series;
- 3 satellites each of the Gorizont, Molnia-1 and Molnia-3 series;
- 1 satellite each of the Nadezhda, Okean, Photon, Raduga-1 series;

These space objects were launched aboard 75 carrier rockets of the Soyuz, Proton, Cosmos, Tsiklon, Molnia and Zenit types.

In five Cosmos-series launches, a single rocket was used to put several satellites into orbit simultaneously: eight on 6 April (Cosmos-2064 to Cosmos-2071); three on 19 May (Cosmos-2079 to Cosmos-2081); six on 8 August (Cosmos-2090 to Cosmos-2095); three on 8 December (Cosmos-2109 to Cosmos-2111); and six on 22 December (Cosmos-2114 to Cosmos-2119).

II. MANNED FLIGHTS

The Mir scientific research manned complex continues to operate in circumterrestrial orbit. In 1990, crews of four Soviet basic expeditions (fifth, sixth, seventh and eighth) and an international Soviet-Japanese crew worked on board the complex.

The programme of work carried out by the crew of the fifth basic expedition (cosmonauts Aleksandr Viktorenko and Aleksandr Serebrov) in weightless conditions for 166 days from September 1989 to February 1990 included geophysical, astrophysical and medical and biological research and technological, biotechnological and technical experiments.

Approximately 200 experiments using cameras and spectrometers were conducted as part of a natural resource survey and environmental studies programme.

The Gallar apparatus was used to carry out a planned research programme on refining basic technological processes for the test production of high-quality semiconductor materials for the prospective development of electronic instruments.

The programme of biotechnical experiments included the testing of a method for producing highly purified medicinal preparations by electrophoresis. Experimental batches of monocrystals of protein compounds were obtained. Comprehensive research was carried out to study the effectiveness of obtaining hybrid producer cells in conditions of weightlessness; this research has opened up a new field in space biotechnology.

The first biotechnological experiment using equipment manufactured in the United States under a commercial agreement has been completed.

A large volume of biological research was conducted with a view to studying the development of plants and amphibians in space-flight conditions, as well as the changes which take place in the cell structures of plant and animal tissue cultures. Experiments were carried out to test various methods of cultivating higher plants.

Regular medical examinations of the crew were conducted. New information was obtained on human beings' ability to work and function during the various stages of the flight.

On 6 December 1989, the cosmonauts reactivated the Kvant-2 module docked with the Mir orbital station and prepared the scientific apparatus and equipment on board the module for future work.

During the flight, the cosmonauts of the fifth basic expedition performed five space walks, during which they installed on the outer surface of the orbital complex new apparatus for conducting geophysical experiments and studying the effects of outer space on samples of different construction materials. Tests were also conducted of new types of space suits, apparatus for the autonomous movement of cosmonauts in outer space, and a special airlock chamber of the Kvant-2 module.

A considerable part of the flight programme of the sixth expedition (cosmonauts Anatoly Solovyev and Aleksandr Balandin), which began its flight to the Mir station on board the Soyuz TM-9 spacecraft on 11 February 1990 and spent approximately half a year in space, was devoted to fundamental research in the field of space materials science and the production under weightless conditions of experimental batches of high-quality semiconductors for the use in the modern micro-electronics industry. The cosmonauts brought the results of the experiments (about three kilograms of semiconductor materials, including monocrystals of gallium arsenide, zinc oxide, germanium and samples of epitaxial silicic structures) back to Earth.

Using photographic and videospectral equipment, the cosmonauts made regular photographic surveys and observations of extensive areas of dry land and of oceans and seas. Such work was carried out both in the interests of branches of the national economy and in order to monitor the ecological state of the atmosphere, bodies of water and vegetation cover in various regions of the planet.

As part of the programme of astrophysical research, surveys of the celestial sphere in the ultraviolet wavelength band were continued and the characteristics of space radiation were measured.

The crew conducted a large volume of medical research and biological experiments. In addition to the development of a technique for cultivating higher plants on board the complex, experiments were carried out to study the effect of space flight on the development and behaviour of birds in weightless conditions. The results of the experiments will be used to create life-support systems for future manned spacecraft.

As part of the programme of biotechnological experiments, the crew carried out experiments to obtain in weightless conditions crystals of various kinds of proteins and cell cultures for research in the field of modern medicine and pharmacology.

The conduct of the crew's extensive flight programme was facilitated to a large extent by the incorporation into the Mir complex of a third Kristall specialized module with a mass of approximately 20 tons. The Kristall module is designed for the test production of semiconductor materials, the purification of biologically active substances for the production of new medicinal preparations, the cultivation of crystals of various proteins and the hybridization of cells, as well as for the conduct of astrophysical, geophysical and technical experiments. In addition to the basic docking facility, the module is equipped with two androgynous peripheral docking units, one of which is designed to work with the Buran space shuttle.

On 10 June 1990, the Kristall module docked with the Mir manned complex on the side of the station's adapter module, as a result of which the overall mass of the large Mir-Kvant-2-Kristall-Soyuz TM-9 space station was 83 tons.

On 11 June 1990, the Kristall module was redocked from the axial to the lateral docking facility of the adapter module of the station. All the operations, including the separation of the module from the station, its relocation in outer space and installation in its regular operating position, were carried out automatically using a manipulator situated on board the module. The redocking of the Kristall module took one hour.

After connecting the systems of the Kristall module with the systems of the manned complex, the cosmonauts conducted a number of experiments using the new equipment and scientific apparatus.

On 4 July 1990, the crew redocked the Soyuz TM-9 transport vehicle from the Kvant astrophysical module to the station's adapter module. Using the manual system of the Soyuz TM-9 transport vehicle, the cosmonauts separated the two spacecraft, manoeuvred them in orbit, steered them around the complex, and moored and docked them. The Soyuz TM-9 was in an autonomous mode for 26 minutes.

During the flight of the crew of the six basic expeditions, which lasted until 9 August 1990, two space walks were performed in order to conduct repair and maintenance work. During the first space walk, the cosmonauts spent 7 hours in outer space; during the second, 3 hours and 31 minutes.

The overall weight of the cargoes brought back to Earth containing materials from research and experiments was 130 kg.

For the first time, a space expedition ended with a positive balance: 84 million roubles was spent on the preparation and conduct of the expedition, and the income from the expedition is estimated at 97 million roubles.

During the seventh basic expedition, which took place from August to December 1990 and lasted for 131 days, the cosmonauts Gennady Manakov and Gennady Strekalov, who arrived at the Mir station on board the Soyuz TM-10 spacecraft, conducted a large volume of scientific and technological research and experiments. A new batch of monocrystals of semiconductor materials with improved characteristics was obtained using several technological units.

As part of the programme of geophysical research, various regions of the planet were photographed and the physical characteristics of the Earth's atmosphere were measured.

Using a set of scientific apparatus installed on the outer surface of the Kristall module, extensive research was conducted on X-rays and gamma and neutron radiation coming from outer space.

Important work in the field of biotechnology was carried out to study the effectiveness of cultivating protein compounds in weightless conditions for use in medicine and pharmacology. The next series of experiments on the further study of the development of higher plants and biological specimens in conditions of weightlessness was also completed.

During a space walk which lasted 2 hours and 45 minutes, the cosmonauts installed a special device for securing the cover of the outer hatch with the body of the Kvant-2 module.

During the last eight days of work in orbit, the crew of the seventh basic expedition worked with a Soviet-Japanese crew which arrived at the Mir station on board the Soyuz TM-11 spacecraft on 4 December 1990. The international crew comprising Gennady Manakov, Gennady Strekalov, Viktor Afanasyev, Musa Manarov and the Japanese cosmonaut-journalist Toehiro Akiyama carried out a planned programme of scientific and

technological and medical and biological research. In addition, the Japanese journalist made many television and radio reports. A total of 37 hours of television coverage of the space flight was broadcast to Japan alone. Between 25 and 30 per cent of Japanese viewers watched coverage from the Baikonur Cosmodrome and from the Mir station.

The crew of the seventh basic expedition returned to Earth together with the Japanese journalist on 10 December 1990; Viktor Afanasyev and Musa Manarov remained in orbit to continue the work of the expedition.

The flight programme of Viktor Afanasyev and Musa Manarov, which is to be carried out over a period of 169 days includes approximately 150 diverse astrophysical, technical, medical, biological and biotechnological experiments, the photographing of the Earth in the interests of various branches of the national economy, and a space walk.

In 1990, the work of the four basic crews and of the Mir orbital complex was supported by four unmanned cargo vehicles of the Progress series: Progress M-3, Progress-42, Progress M-4 and Progress M-5, launched on 1 March, 6 May, 15 August and 27 September, respectively.

It should be noted that, for the first time, an experimental prototype of a returnable ballistic capsule designed to convey the results of scientific research to Earth, was installed on Progress M-5. During the flight of the seventh basic expedition, the capsule was used to transmit some of the materials (approximately 50 kg to Earth. The separation of the capsule was effected on 26 November 1990 when the Progress M-5 vehicle began the transition to a descending trajectory. In the atmosphere, the capsule's parachute system was deployed for the final descent.

By carrying out a Soviet-Japanese flight on commercial terms, the Soviet manned space programme made a first step towards participating in the international space services market.

The Soviet commercial manned programme planned for 1991 and 1992 includes four international flights with the participation of cosmonauts from Austria, France, Germany and the United Kingdom.

III. PROGRAMMES FOR THE APPLICATION OF SPACE TECHNOLOGY

1. In 1990, the USSR continued to work on the use of space technology for hydrometeorology. To fill a gap in the existing space meteorological system, it launched a Meteor-2 and a Meteor-3 satellite on 28 June and 28 August 1990 to gather global weather information (images of clouds and of the ice and snow cover) in the visible and infrared bands of the spectrum and measure radiation levels in circumterrestrial space, transmitting this information to receiving facilities in the USSR and foreign countries.

Information from the Meteor-2 and Meteor-3 satellites is relayed to the main and regional processing centres of the USSR State Committee on Hydrometeorology and to automatic receiving stations; the information is transmitted for use by regional and local weather-forecasting centres and is also distributed through communications channels to other users, including foreign users.

The Resurs space subsystem (Cosmos-1939 satellite) is still in operation. High- and medium-resolution space data on the state of the Earth's natural resources are relayed to the main and regional processing centres and made available to users from various branches of the national economy on the basis of requests and other agreements; such data are used by the USSR State Committee on Hydrometeorology to solve scientific and operational problems.

The Okean-01 satellite was launched on 28 February 1990 to supplement the first stage of the Okean space subsystem, designed to study oceans and seas. The results of an analysis of the radar data obtained from the oceanographic satellite were used to develop methods for reproducing the surface wind vector in areas of atmospheric convection and atmospheric waves and also for forecasting hail conditions. The monograph entitled "Radio-location of positions on the Earth's surface from outer space", which summarizes the scientific data obtained from the side-looking radar of the Okean satellite, has been published.

In space meteorology and oceanography, research continued on the collection, analysis of use of satellite hydrometeorological information for the purpose of providing data to various branches of the national economy and improving weather forecasting.

Improvements were made on the global operational system for the thermal sounding of the atmosphere using measurement data from the Meteor satellite. Models were constructed of systems for the remote sensing of meteorological parameters of the atmosphere on a regional scale with a spatial resolution of 80 kilometres and, on a local scale, with a spatial resolution of 20 kilometres using measurement data obtained from apparatus for the vertical sounding of the atmosphere from a United States weather satellite. A system for the effective monitoring of the sea-ice cover and of hydrometeorological conditions in polar waters is being operated on an experimental basis. The system, which provides information to an extensive network of subscribers, is based on existing observation (meteorological and oceanological) and communication satellites. Experimental methodology and software for the computer processing of raw data in an interactive mode has been developed.

International cooperation is being carried out on a bilateral basis with Canada and Finland in the field of satellite data processing and interpretation; with Germany, Italy and the United States in the exploration and peaceful uses of outer space; with France in the study of the Earth's radiation balance and in the field of space meteorology; and on a multilateral basis under the programmes of the Intercosmos Council, with Bulgaria, Cuba, Czechoslovakia, Hungary, Mongolia, Poland, Romania and Viet Nam.

As part of the programme for the study of circumterrestrial space, a series of experimental and theoretical studies of local and non-local processes in circumterrestrial space has been carried out by active measurement methods through the creation of artificial ionic clouds in the ionosphere. Model calculations demonstrated, and a series of active experiments in the middle-latitude ionosphere confirmed, the existence of threshold conditions for the development of plasma instabilities which lead to the formation of the fine structure of artificial ionic clouds.

A new generation of models of the upper atmosphere were developed using a combination of hydrodynamic description and an empirical simulation.

On Kheys Island (Franz Josef Land), a new Lidar station was put into operation for the purpose of measuring the temperature and atmospheric density at altitudes of 32 to 80 kilometres. On the scientific research vessel Professor Wiese, measurements were taken of the parameters of the upper strata of the atmosphere with the aid of a Rayleigh Lidar. Latitudinal cross-sections of temperature and atmospheric density at altitudes of 30 to 75 kilometres, and of stratospheric aerosol at altitudes of 15 to 30 kilometres, were obtained.

The systematization and analysis of data on solar cosmic rays by cycles and phases of the twentieth, twenty-first and first half of the twenty-second cycle (from 1964 to 1990) made it possible to establish important properties of solar proton events in 1989. Surveys made by the Meteor satellite in 1989 registered powerful solar proton flares, which were the source of disturbed radiation conditions in circumterrestrial space. In the current twenty-second cycle, solar activity has increased considerably in solar latitudes above 25°. A comparative analysis of the magnitudes of the helio-geophysical parameters makes it possible to conclude that 1989 was a year of maximum solar cosmic ray activity for the period under consideration.

The development and manufacture of technology for the on-board equipment complex and corresponding monitoring and testing apparatus for the Alice Soviet-French space project was completed; the project involves the joint development of a space Lidar to study the atmosphere from the Soviet Mir orbital station.

In 1989 and 1990, research on the ozonosphere above Antarctica continued. It was discovered that in 1989 the overall ozone content above the Molodezh station had decreased to 300 Dobson units, as in 1987. In the spring of 1990, the spring anomaly was also observed; however, the degree of ozone depletion was somewhat less than it had been in 1989.

As a result of the joint efforts of Soviet and United States experts, agreement was reached on the organizational and technical aspects of installing a United States apparatus on board the Soviet Meteor-3 satellite (TOMS project) to measure overall ozone content for the purpose of studying global and regional ozone depletion.

2. The development of outer space exploration has opened new vistas for the study of the Earth's environment and natural resources. More than 300,000 photographs of the Earth's surface have been obtained using automatic Earth-observation equipment mounted on Resurs satellites and installed in manned orbital complexes. The space survey materials obtained from the Resurs satellite system cover practically the entire territory of the USSR, as well as 30 per cent of the territory of foreign countries. Many regions have been photographed more than once. In 1990, four satellites of the Resurs-F series were launched into space. The Resurs-F satellite launched on 7 September 1990 carried German scientific equipment designed to conduct biotechnological experiments in conditions of microgravity.

In 1990, more than 1,000 scientific and production organizations from 22 branches of the country's national economy, as well as firms and organizations from a number of countries, made use of space photography.

Space data were used for comprehensive study and mapping of the resources of Tadzhikistan, Uzbekistan, Kirghizia, Kalmykia, the Stavropol region, Kalinin Oblast and other territories.

The foreign trade organization Soyuzkarta All-Union Association and foreign firms and organizations have concluded a number of long-term contracts and agreements on the provision of space photography products.

In 1990, space photo production was made available on commercial terms to Brazil, Peru, Cuba, Japan, the Syrian Arab Republic, China, Yemen, Australia, France, Afghanistan and to the specialized agencies of the United Nations, in particular the Food and Agriculture Organization of the United Nations.

Negotiations are in progress with firms of other countries on supplying them with space products under long-term agreements.

3. In 1990, the USSR continued to improve its communications and broadcasting means through the use of satellite systems.

The communications network for transmitting telephone, telegraph and facsimile information using the Gorizont satellite and the Orbita, Nauka and other ground stations were modernized and expanded.

The successful expansion of the systems for distributing the Moskva and Ekran television programmes continued to be developed successfully. There are approximately 9,000 stations for receiving television broadcasts from those two systems which make use of the Gorizont (Moskva) and the Statsionar-1 (Ekran) satellites.

More than 20 new receiving stations were set up in 1990 for the Moskva-Globalnaya system for retransmitting Soviet television programmes to Soviet missions abroad. There are now more than 50 such stations.

Satellite communications using small ground stations with outlets to the country's exchange telephone network are being developed and introduced.

A regional television-programme distribution network using the Luch satellite in the 11/14 GHz frequency range is being put in place for Kazakhstan. This satellite system will be put into operation at the end of 1991. It is expected that approximately 250 stations with 4-m-diameter antennas will be set up. There are plans to establish similar systems in the near future in other regions of the USSR.

Work is being conducted on determining the prospects for developing the space and ground segments on the basis of small, medium and heavy satellite systems in order to meet the country's needs with regard to services in long-distance mainline, intra-zonal, local and international communications.

The small satellites (up to 2.5 tons) include the Express communication satellites and the Gals direct-television-broadcasting satellites, which are still being developed, and also spacecraft for mobile satellite communications. Compared to the Gorizont satellites in operation, the Ekspress satellites will offer greater accuracy of retention in orbit, improved power supply parameters and a longer active lifetime, and optimal service zones will be established at different positions since the on-board transmitting and receiving-transmitting antennas can be reoriented, which makes it possible to increase considerably the potential of satellite communication and broadcasting systems.

The development of the hardware components in the system for satellite television broadcasting in the 12 GHz range using the Gals satellite is near completion.

The new satellite will have narrow rays with sufficiently high effective isotropic radiated energy making it possible to direct television programme reception to receiving stations with approximately 0.9-m-diameter antennas.

Between 1992 to 1994 the system will provide republican and regional television programmes in the territory of the Soviet Union.

The medium-weight satellites (up to 4.5 tons) will also include the Gelikon television-programme relay satellite. Work is currently being carried out to manufacture multi-channel Gelikon satellites, which will be used, like the Gals satellites, for direct television broadcasting and which increase the number of television programmes with account taken of time zones and national interests.

International cooperation in the field of space communications developed further in 1990. Through the Intersputnik system it was possible to provide uninterrupted telephone communication, exchange television programmes, modernize equipment in ground stations and lease satellite relay stations to foreign countries.

Under the Intercosmos programme, research was conducted in the field of satellite communication and broadcasting systems. Special mention might be made here of the Dubna-Intercosmos International Experimental Satellite Communications Centre, where new equipment was tested and statistical data on radiowave propagation were collected and analysed. The Gorizont satellite, which is specially equipped with a Mayak transmittor and was placed in geostationary orbit in 1990, is being used to carry out further work under the Intercosmos programme.

4. The development of space systems for the purposes of navigation, and search and rescue continued. Within the framework of the International Maritime Satellite Organization (Inmarsat), the Soviet Union is closely cooperating with other countries to improve the communications of vessels, aircraft and land vehicles.

In the USSR two international-satellite-communication centres are in operation in Odessa and Nakhodka. In accordance with the plans of Inmarsat, the USSR Ministry of the Merchant Marine is holding talks with foreign organizations and companies aimed at modernizing the centres in order to carry out work by means of the second-generation Inmarsat satellites, the first of which was launched on 30 October 1990. The production of a satellite-communication shipboard apparatus for maritime users was arranged and plans were made to manufacture communications equipment for aircraft and land vehicles.

More than 600 of the Soviet Union's satellite-communication stations are currently operating in the Inmarsat system.

The Soviet side has repeatedly submitted competitive-bidding proposals for launching second- and third-generation Inmarsat satellites by means of the Soviet Proton launch vehicle, has continued to follow a policy in the Inmarsat Council aimed at protecting the interests of users, inter alia with regard to the acquiring of property and services by Inmarsat from the companies and organizations that offer the best combination of quality, price and most favourable conditions for delivery.

In the past two years, the All-Union association Morsvyazsputnik won three bidding competitions for conducting scientific research on marketing questions in the USSR and the idea of using the GPS and Glonass systems in conjunction with the Inmarsat satellite-communication system, and also for servicing vessels in the Pacific region in testing the reliability of alarm- and distress-signal transmission systems.

In accordance with the intergovernmental agreement between the USSR, the United States, Canada and France of 1 July 1988, cooperation is taking place in the development, use and operation of the Cospas-Sarsat international satellite system, designed to determine the position of ships and aircraft in distress.

As part of that system, four artificial earth satellites, 11 coordinating and computing centres and 20 data-receiving and processing centres situated

in various countries of the world are currently operating around the clock. There is close technical and operational interaction among all coordinating and computing centres in the Cospas-Sarsat system.

The number of users of the Cospas-Sarsat system has increased significantly in both the USSR and other countries. The joint use of the system by the agencies and organizations of many countries in conducting 616 search-and-rescue operations saved 1,664 human lives between September 1982 and the end of July 1990.

On 27 February 1990, the second Nadezhda satellite was launched for the Cospas-Sarsat system.

5. The next Photon satellite was launched into space on 11 April 1990 as part of the programme on space materials research. During a period of 16 days experiments aimed at producing albumen crystals in microgravity conditions and enhanced-performance semiconductors were carried out and the technology for their experimental industrial production was developed. A technological experiment using a French apparatus was also conducted on the satellite.

IV. Scientific programmes for the investigation of outer space

1. Soviet scientists carried out work on a number of scientific space projects.

Observations were conducted throughout the year using the Roentgen, Granat and Gamma orbital astrophysical observatories. Their results are very important in order to carry out basic research in the field of high-energy astrophysics.

The Roentgen observatory is part of the Kvant orbital module docked with the Mir orbital station. The entire scientific apparatus is designed to investigate the spectral and temporal characteristics of space X-ray radiation sources in a broad energy range from 2 to 800 keV. The most important scientific result of the work carried out by the observatory was the discovery of hard X-ray radiation from supernova SN 1987 A in the Large Megellanic Cloud. Experiments are continuing at the present time on board the Roentgen observatory. The apparatus includes:

- An X-ray telescope with aperture mask;
- A high-energy scintillation X-ray telescope;
- A gas scintillation spectrometer;
- A Pulsar X-1 hard X-ray telescope and spectrometer.

The gross weight of the observatory is 1,000 kg. It has a power consumption of about 350 W, and a data output of up to 80 megabits per 24-hour

period. During the work carried out on board the Roentgen observatory, 2,300 observation sessions of various X-ray sources were conducted.

The Granat observatory was put into high-apogee orbit on 1 December 1989. It includes:

- An X-ray telescope with a coded aperture (USSR);
- An X-ray telescope and spectrometer (USSR);
- A gamma-telescope with a coded aperture (France);
- A set of gamma-burst detectors (France);
- A set of gamma-burst detectors (USSR);
- A wide-angle X-ray monitor (Denmark);
- An X-ray optical telescope on a Podsolnukh rotary platform (USSR-Bulgaria).

To date, 250 sessions, each lasting up to 20 hours, have been conducted.

The most important results up to the present time are:

- Localization of the positron annihilation line in the central region of the galaxy;
- Mapping of the central region of the galaxy and the discovery of five new sources in that region;
- Accurate measurement of the periods and period changes of X-ray pulsars;
- Detection of the millisecond structure of gamma bursts.

The Gamma space observatory with a Gamma telescope and Pulsar X-2 spectrometer on board was launched on 11 August 1990.

Poland, the USSR and France are participating in the project.

The first months of work by the observatory indicated that the observatory's auxiliary systems fully meet project specifications.

Observations were carried out of the central region of galaxy. The data obtained is being processed. The preliminary results of the processing enable one to posit the existence of the temporal variability observed earlier in one of the sources in this region.

The observations of the pulsar in the Vela constellation in the central region of the galaxy have now been completed. They made it possible to

isolate the pulsating component of its gamma radiation. This also demonstrated the possibility of recording the temporal and spectral characteristics of space gamma sources by means of a gamma telescope.

In addition to the astrophysical observations conducted under the observatory's research programme, observations of burst phenomena on the surface of the Sun will be carried out. At the same time, the charged particles of cosmic rays, particularly in the Earth's radiation belts, will be monitored.

Under the programmes carried out jointly with foreign countries, work was conducted with a Czechoslovak S2-AK subsatellite, which was tracked and controlled by Czechoslovak specialists at the ground station in Panska Ves (Czechoslovakia). An electron energizing effect occurring in the vicinity of a space vehicle when a very low-frequency transmitter is operating was detected by means of this satellite. The generation of very low-frequency oscillations by the antenna produces a disturbed zone around the satellite which measures approximately 20-40 km and emits intense oscillations. An injection of the neutral gas xenon from the space vehicle produces a plasma cloud whose density is about 1.5-2 times greater than the density of the surrounding plasma and causes intensive very low-frequency oscillations.

2. Preparatory work for carrying out the next long-term international scientific projects was conducted in 1990.

The Relikt-2 project, which is scheduled to be implemented in 1992, is designed to carry out multi-frequency measurements of the anisotropy of background radiation in the 20-200 GHz frequency range.

The aim of this research is to study the basic questions of the origin and development of the universe, construct a large-scale radio map of the celestial sphere in the millimetre wavelength range, and determine the nature of the distributed radiation sources in our galaxy.

Experts from Bulgaria, Czechoslovakia, Poland, the Soviet Union and the European Space Agency are participating in the development of the scientific apparatus for the spacecraft to be launched under the project.

In 1990, mechanical and thermal testing of the cryogenic receiving complex was carried out and the possibility of cooling the apparatus to a temperature of 100 K was demonstrated. The techniques for adjusting and testing the cryogenic radiometric modules were perfected.

The possibility of improving orbit characteristics by using the Moon's gravitational field was demonstrated in joint work with scientists from the United States.

The Radioastron project is designed to create a ground-space radio interferometer for astrophysical observations. This interferometer includes a 10-m-diameter space-based radio-telescope on board a Spektr-R spacecraft,

which will be put into an elliptical orbit with a 24-hour orbital period and an 80,000-km apogee. Plans have been made to construct by means of the telescope high-quality radio-images of astrophysical objects with angular resolution far superior to that achieved in all the ranges of the electromagnetic spectrum.

Radioastronomical observatories and scientific and technical organizations and firms from 13 countries are participating in the development of the project's on-board and ground-based scientific equipment.

By the end of 1990, most of the scientific instruments had been tested and a detailed draft research programme had been drawn up.

The Spektr-R spacecraft is scheduled for launching at the end of 1993.

Under the Interbol project, two satellite pairs are to be launched in 1992. One pair (a satellite and a subsatellite) has an orbit with an apogee of about 20,000 km and traverses the auroral regions of the Earth's magnetosphere. The distance between the spacecraft varies from 100 to 1,000 km. The second pair has an orbit with an apogee of 150,000 km and is scheduled to carry out research into the processes in the tail and edges of the Earth's magnetosphere. The distance between the main satellite and the subsatellite varies from 1,000 to 10,000 km. This configuration of space vehicles enables research to be done both into the global interconnections between phenomena in the solar-terrestrial system and into the ephemeral patterns of phenomena in critical regions of the Earth's magnetosphere.

Under the projects, tests continued in 1990 on scientific instruments and space vehicle systems. Theoretical work was also carried out on the dynamics of charged particles in the complex magnetic geometry which is characteristic of circumterrestrial space, and questions concerning the acceleration and heating of plasma and the collective interaction of particles and waves in a magnetosphere environment were resolved.

Specialists from the USSR, Germany, Czechoslovakia, Bulgaria, Poland, Romania, France, Italy, Sweden, Canada and the European Space Agency are cooperating in the Interbol project.

Under the Regata project, a new type of space vehicle equipped with solar sails that maintain the orientation of the vehicle is being developed. The system adopted in such vehicles (space Regata) will make it possible for highly accurate, detailed measurements to be made, between 1994 and 1998, of plasma and magnetic-field parameters in the Earth's magneto-plasma sheath. Research will be conducted in equatorial orbits at distances of the order of 20,000 to 30,000 km, where basic interaction takes place between cold and hot plasma, in polar orbits and orbits which are held in the tail of the magnetosphere with the assistance of the Moon's gravitational influence, and also in the forward and rear libration points.

In 1990 work was done on systems planning for the space vehicle and the scientific apparatus for plasma research and research into electromagnetic

fields. Full-scale mock-ups and a thermal mock-up were developed. Materials for the solar sails were selected and tested.

Specialists from the European Space Agency, the United States, Canada and a number of European countries intend to participate in the project.

The launching of the Spektr-Roentgen-Gamma international astrophysical observatory is planned for 1993.

The observatory will be equipped with the following apparatus:

- A Soviet-Danish X-ray concentrator telescope with a focal length of 8 m and an effective area of 3,500 sq. cm., and which has a sensitivity range of 0.3 to 20 keV and opens out in space;

- A grazing-incidence high-resolution X-ray telescope (USSR, United Kingdom, Italy, Germany);

- An X-ray telescope with a coded aperture (USSR, Italy) for research into the spectra of nuclei of active galaxies and variable X-ray sources in the hard X-ray range;

- A normal-incidence telescope for the extreme ultra-violet range (USSR, Switzerland, United Kingdom, Germany);

- A wide-angle X-ray monitor (USSR);

- An all-sky telescope (USSR, United States);

- Equipment for research into gamma-bursts in outer space (USSR);

- An X-ray polarimeter (United States, USSR, Italy, United Kingdom);

- Detectors for gamma-burst spectroscopy in the 100 keV to 100 MeV range;

- The model of the gamma-burst instrument package also includes a cooled detector of high-purity germanium for high-resolution gamma-burst spectroscopy.

The first mock-ups of the scientific instruments were made in 1990. The work of building the space vehicle and its auxiliary systems is being carried out. The preparatory, testing and calibration stages for the on-board apparatus begin in 1991.

Specialists from Australia, Canada, Czechoslovakia, Denmark, France, Germany, Hungary, Italy, Switzerland, the United Kingdom and the United States are taking part in the work of the construction of the observatory.

The Mars-94 project, in which scientific institutions from 20 countries are participating, provides for the launching towards Mars of two identical

space vehicles in October 1994. Eleven months after the launching, the vehicles will approach the planet and become artificial satellites of Mars. Each vehicle will place a "landing party" on the surface of Mars: an aerostat probe, small stations, penetrators and a small Mars surface vehicle.